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# [54] SYSTEM AND METHOD FOR SLIDING CLUTCH ENGAGEMENT UNDER TOOTH BUTT OR TORQUE LOCK CONDITIONS

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[58] Field of Search ........ 477/123, 124; 74/335, 74/336 R; 364/424.1

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5,109,721 5/1992 Boardman et al. ........ 74/336 R
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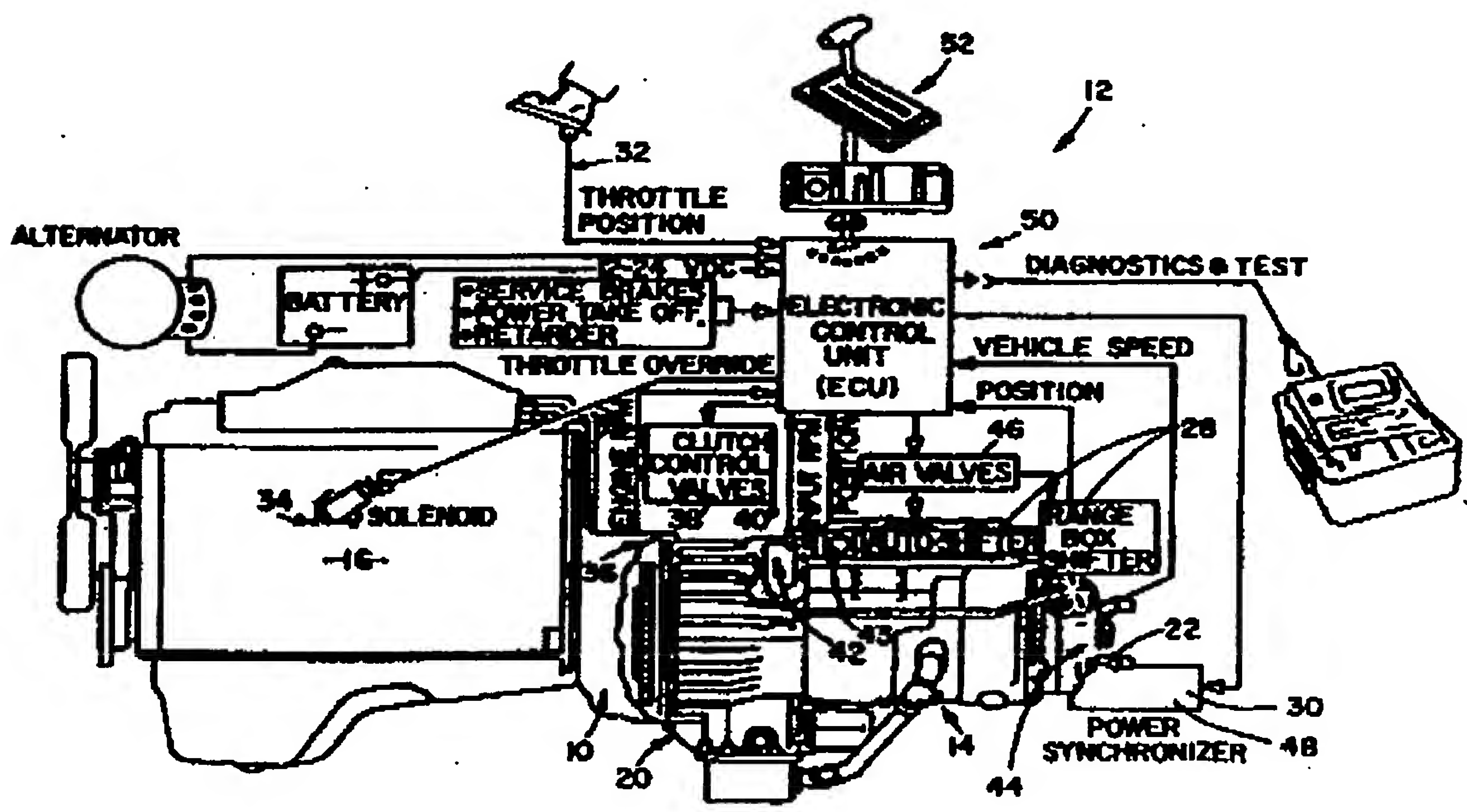
[57] ABSTRACT

A system and method are disclosed for controlling a shift event in a transmission wherein a shift actuator develops a force to effect the engagement of a clutch collar and a gear. The method comprises detecting when a non-fully engaged condition of the clutch collar and the gear occurs, indicating either a tooth butt or torque lock condition, and then pulsing the shift actuator, when the non-fully engaged condition is detected, between a relatively low force and a relatively high force to disturb the clutch collar and the gear out of the non-fully engaged condition. The detecting step comprises examining either the axial position of the clutch collar or the axial position of a shift rail operatively connected to the clutch collar with a rail position sensor. Preferably, a signal having a modulated pulse width and a frequency of between about 5 and 20 Hertz is sent to the shift actuator. The system which embodies this method is disclosed in the forms of an automated mechanical transmission having sliding clutch collars and a transmission system having a standard friction master clutch interposed the engine and the transmission.

21 Claims, 4 Drawing Sheets



# SYSTEM AND METHOD FOR SLIDING CLUTCH ENGAGEMENT UNDER TOOTH BUTT OR TORQUE LOCK CONDITIONS

## TECHNICAL FIELD

This invention relates to a system and method for controlling the operation of an automated mechanical transmission of a motor vehicle, and more particularly to such a system and method for sensing tooth butt and/or torque lock conditions and for taking action to overcome these conditions. .

## BACKGROUND ART

Automatic mechanical transmission systems comprising mechanical transmissions and controls and actuators to automatically shift same, usually electronically controlled in accordance with sensed inputs and predetermined logic rules, are known. Examples of such systems may be seen by reference to U.S. Pat. No. 4,648,290, U.S. Pat. No. 4,642,771, U.S. Pat. No. 4,595,986, U.S. Pat. No. 4,527,447, U.S. Pat. No. 4,361,060, U.S. Pat. No. 4,140,031 and U.S. Pat. No. 4,081,065, the disclosures of which are hereby incorporated by reference. Such systems may also be seen by reference to SAE Paper No. 831776 titled "AUTOMATED MECHANICAL TRANSMISSION CONTROLS," the disclosure of which is hereby incorporated by reference. Fault tolerance logic routines for automatic transmissions are known as may be seen by reference to U.S. Pat. No. 4,922,425, U.S. Pat. No. 4,849,899 and U.S. Pat. No. 4,899,279, the disclosures of which are hereby incorporated by reference.

Electronic and other engine fuel control systems wherein the fuel supplied to the engine may be modulated to provide a desired engine speed, regardless of the operator's setting of the throttle pedal, are known in the prior art. Such systems may be seen by reference to U.S. Pat. No. 4,081,065, U.S. Pat. No. 4,361,060, U.S. Pat. No. 4,792,901 and by reference to SAE J1922 and SAE J1936 electronic engine control standards, and related standards SAE J1708, J1587 and J1843, all of which are hereby incorporated by reference.

With automated transmission systems, particularly those derived from a manual nonsynchronized mechanical transmission, the conditions of tooth butting and/or tooth buzzing may occur, for instance when the vehicle starts from a stop. Tooth butting occurs when the ends of the teeth of the jaw clutch members come into abutment rather than axial interengagement, for instance when the rotational speeds of a sliding clutch and of a gear are equal or nearly equal when a gear engagement is initiated. Eventually the speeds of the two jaw clutch members will change and slip occurs causing a gear buzz (chatter) during the ensuing engagement. Tooth buzzing thus occurs when the ends of the butted jaw clutch teeth go into a grinding relative rotation rather than into axial interengagement as one of the clutch members is rotated to overcome butting. In such transmission systems, especially if the master friction clutch or torque disconnect clutch is not closely modulated, it is desirable to provide logic routines for detecting and for overcoming such tooth butt or tooth buzz conditions.

Furthermore, during a shift sequence of the gears of a transmission, it is possible to not fully engage the sliding clutch due to torque lock. Torque lock occurs when, due to torque being transmitted, a higher frictional force exists than the input force trying to slide the clutch into full engagement. During torque lock, a sudden torque decrease or reversal may allow the gear to fully engage, but until that occurs all of the power flow for the gear is through the partial engagement. Under normal torque lock conditions, the sliding clutch will not engage further until a torque reversal has occurred. The same phenomenon occurs during a gear butt condition.

A conventional method of recovery from tooth butting and tooth buzzing has been to continue pushing the clutch collar and gear toward engagement, or to recycle the gear box back to neutral and reinitiate engagement multiple times until complete, as disclosed by U.S. Pat. No. 5,099,711, assigned to the assignee of the present invention and hereby incorporated by reference.

## SUMMARY OF THE INVENTION

The present invention is a system and method for controlling a shift event in a transmission wherein a shift actuator develops a force to effect the engagement of a clutch collar and a gear. The method comprises detecting when a non-fully engaged condition of the clutch collar and the gear occurs, indicating either a tooth butt or torque lock condition, and then pulsing the shift actuator, when the non-fully engaged condition is detected, between a relatively low force and a relatively high force to disturb the clutch collar and the gear out of the non-fully engaged condition. The detecting step comprises examining the axial position of either the clutch collar or a shift rail operatively connected to the clutch collar. Preferably, a signal is applied to the shift actuator having a modulated pulse width and a frequency of approximately 10 Hertz. The system which embodies this method is also disclosed in the form of an automated mechanical transmission having sliding clutches.

Accordingly, it is an object of the present invention to provide a new and improved system and method for detecting and overcoming a tooth butt and/or torque lock condition in the transmission of a motor vehicle.

This and other objects and advantages of the present invention will become apparent from a reading of the detailed description of the preferred embodiment in connection with the drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of an automatic mechanical transmission of the present invention including a torque converter;

FIG. 2 is another schematic illustration of the automatic mechanical transmission;

FIG. 3 is a partial view, in section, of the automatic mechanical transmission; and

FIG. 4 is a transition diagram of the control system/method logic of the present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

FIGS. 1, 2 and 3 schematically illustrate a torque converter lock-up and disconnect clutch assembly 10 and an automatic mechanical transmission system 12 utilizing same. The term "automatic mechanical transmission system" as used herein means a system comprising at least a throttle device controlled heat engine 16, a multi-speed jaw clutch type change gear transmission 14, a nonpositive coupling device such as a master fric-

tion clutch and/or a fluid coupling 10/20 interposed the engine and the transmission, and a control unit 50 for automatically controlling same. Such systems will, of course, also include sensors and/or actuators for sending input signals to and/or receiving command output signals from the control unit. While the present invention is suited for use in connection with transmission systems having a torque converter and torque converter lockup/disconnect clutch, the invention is also particularly applicable to transmission systems having a standard friction master clutch drivingly interposed the engine and the transmission.

The automatic mechanical transmission system 12 of the present invention is intended for use on a land vehicle, such as a heavy duty truck, but is not limited to such use. The automatic mechanical transmission system 12 illustrated includes an automatic multi-speed mechanical change gear transmission 14 driven by a prime mover throttle device controlled engine 16 (such as a diesel engine) through a fluid coupling or torque converter assembly 20. The output of the automatic transmission 14 is an output shaft 22 which is adapted for driving connection to an appropriate vehicle component such as the differential of a drive axle, a transfer case, or the like as is well known in the prior art.

As will be discussed in greater detail below, the torque converter lock-up and disconnect clutch assembly 10 includes two separate, independently engageable clutches, preferably friction clutches, a torque converter disconnect clutch 24 and a torque converter lock-up or bypass clutch 26. The transmission 14 includes a transmission operating mechanism 28 which is preferably in the form of a pressurized fluid actuated shifting assembly of the type disclosed in above-mentioned U.S. Pat. No. 4,445,393. The transmission also preferably includes a power synchronizer assembly 30 which may be of the type illustrated and disclosed in above-mentioned U.S. Pat. No. 3,478,851, U.S. Pat. No. 4,023,443 or U.S. Pat. No. 4,614,126. The present invention is also applicable to automated mechanical transmission systems not including a power synchronizer assembly.

The above-mentioned power train components are acted upon and monitored by several devices, each of which are known in the prior art and will be discussed in greater detail below. These devices may include a throttle position monitor assembly 32 which senses the position of the operator controlled vehicle throttle pedal or other fuel throttling device, a throttle control 34 which controls the supply of fuel to the engine, an engine speed sensor assembly 36 which senses the rotational speed of the engine, a torque converter disconnect clutch and lock-up clutch operator 40 which operates the torque converter disconnect and lock-up clutches, a transmission input shaft speed sensor 42, a transmission output shaft speed sensor 44, a transmission shifting mechanism operator 46 for controlling the operation of transmission shifting mechanism 28 and/or a power synchronizer mechanism actuator 48 for controlling the operation of power synchronizer mechanism 30. The throttle control 34 may simply be an override device to reduce ("dip") fuel to the engine to a set or variable level regardless of the operator's positioning of the throttle pedal. Alternatively, the throttle control may be a portion of an electronic engine control complying with the above-mentioned SAE J1922, SAE J1939 or a similar standard.



The above-mentioned devices supply information to and/or accept commands from an electronic central processing unit (ECU) 50. The central processing unit or controller 50 is preferably based on a digital microprocessor, the specific configuration and structure of which form no part of the present invention. The central processing unit 50 also receives information from a shift control or mode selector assembly 52 by which the operator may select a reverse (R), a neutral (N), or several forward drive (D, $D_L$) modes of operation of the vehicle. Typically, the D mode of operation is for on-highway vehicle travel while the $D_L$ mode of operation is for off-road operation.

The system also typically includes various sensors, circuits, and/or logic routines for sensing and reacting to sensor and/or actuator failures. As is known, the central processing unit 50 receives inputs from the various sensors and/or operating devices. In addition to these direct inputs, the central processing unit 50 may be provided with circuitry and/or logic for differentiating the input signals to provide calculated signals indicative of the rate of change of the various monitored devices, means to compare the input signals, and/or memory means for storing certain input information, such as the direction of the last shift, and means for clearing the memory upon occurrence of predetermined events. Specific circuitry for providing the above-mentioned functions is known in the prior art and an example thereof may be seen by reference to above-mentioned U.S. Pat. Nos. 4,361,060 and 4,595,986 and/or by reference to a technical paper entitled "THE AUTOMATION OF MECHANICAL TRANSMISSIONS" published proceedings of a joint IEEE/SAE conference entitled International Congress 20 on Transportation Electronics, IEEE Catalog Number 84CH1988-5, the disclosure of which is hereby incorporated by reference. As is well known in the operation/function of electronic control units, especially microprocessor based ECUs, the various logic functions can be performed by discrete hardwired logic units or by a single logic unit operating under different portions or subroutines of the control system logic rules (i.e. the software).

FIG. 1 shows a more detailed schematic illustration of the torque converter 20 and torque converter lock-up and disconnect or interrupt clutch assembly 10 drivingly interposed engine 16 and automatic change gear transmission 14. The torque converter assembly 20 is conventional in that it includes a fluid coupling of the torque converter type having an impeller 54 driven by the engine output or crankshaft 56 through a shroud 58, a turbine 60 hydraulically driven by the impeller and a stator or runner 62 which becomes grounded to a housing 64 via a one-way roller clutch 66 carried by a shaft 68 grounded to the housing 64. Shroud 58 also drives a pump 70 for pressurizing the torque converter, lubricating the transmission, selectively pressuring the transmission shifting mechanism 28, and/or power synchronizing mechanism 30 and/or operating the disconnect and bypass clutches 24 and 26. Pump 70 may be of any known structure such as, for example, a well known crescent gear pump.

The transmission 14 includes an input shaft 72 driven by the engine 16 via the torque converter assembly 20 and/or lock-up and disconnect clutch assembly 10. Transmission input shaft 72 carries a connecting member 74 fixed thereto for rotation therewith. Connecting member 74 includes a portion 76 associated with the